# An *in vitro* study of the torsional properties of new and used K3 instruments

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## Abstract

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**Aim** To compare torque and angle of rotation at fracture of new and used K3 rotary instruments. The relation between size of instrument and torque at fracture was also investigated.

**Methodology** Nickel–titanium (Ni-Ti) .06 K3 rotary instruments were used in a crown-down manner at 300 r.p.m. to prepare canals in resin blocks. The torque and angle of rotation at fracture of new and the used Ni-Ti .06 K3 rotary instruments (sizes 15–40) were determined according to ANSI/ADA Specification no. 28. Analysis of variance was used to compare the torque and angle of rotation at fracture amongst the different sizes of the new instruments and between new instruments and instruments of the same size, which had been used in resin blocks ($\alpha = 0.05$). The relationship between torque at fracture and size of instrument was subjected to regression analysis.

**Results** Torque at fracture of the new instruments increased significantly with the diameter. The used instruments (sizes 15, 20, 30, 35 and 40) had lower torque at fracture compared to the new ones ($P < 0.0001$). The means of angle of rotation at fracture between the different sizes of new instruments were significantly different ($P < 0.0001$) except for sizes 15–20 ($P = 0.2561$). The used instruments (sizes 20–40) had lower angle of rotation at fracture compared to the new ones ($P < 0.05$). A linear relationship was found between the size of the file and the torque at fracture for the new instruments ($r^2 = 0.84$; $P < 0.0001$) and the used ones ($r^2 = 0.82$; $P < 0.0001$).

**Conclusions** In general, the results suggested that the torque and angle of rotation at fracture were significantly affected by the repeated use of .06 K3 instruments in resin blocks.

**Keywords:** angle at fracture, K3, torque at fracture.

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## Introduction

Instrument fracture is a serious concern in root-canal treatment. Several studies have evaluated the influence of various factors on the fracture of nickel–titanium (Ni-Ti) endodontic rotary instruments (Barbakow & Lutz 1997, Pruett *et al.* 1997, Silvaggio & Hicks 1997, Mandel *et al.* 1999, Yared *et al.* 2001a,b). It is important for the clinician to have detailed research information to provide a rational basis for instrument selection. According to ANSI/ADA Specification no. 28 (ANSI/ADA 1988), the torsional properties of endodontic instruments can be evaluated as torque and angle of rotation required to cause instrument fracture. Previous studies have investigated the torsional properties of various brands of Ni-Ti endodontic rotary instruments. Sattapan *et al.* (2000) evaluated the torque at fracture of Quantec Series 2000 rotary Ni-Ti instruments (TycomCorp, Irvine, CA, USA). The instruments fractured at torque values varying from 2.26 to 19.63 Nmm. The torque at fracture of Lightspeed instruments (Lightspeed Technology, Inc., San Antonio, TX, USA) ranged from 1.96 to 41.96 Nmm. The angle of rotation at fracture varied from 637.2 to 1710° (Marsicovetere *et al.* 1996). Silvaggio & Hicks (1997) investigated the torsional properties of Ni-Ti ProFile .04 Series 29 instruments (Tulsa Dentsply, Tulsa,

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OK, USA). Peters & Barbakow (2002) tested selected Ni-Ti ProFile .04 rotary instruments (Maillefer Dentsply, Ballaigues, Switzerland). The torque and angle of rotation at fracture for sizes 15, 35 and 60 ranged from 3.59 to 31.68 Nmm and from 514.3° (size 60) to 614.1° (size 35), respectively.

Instrument fracture results from cyclic fatigue or torsional stress (Sattapan *et al.* 2000). Fracture from cyclic fatigue is more likely to occur when instruments are rotated in root canals with abrupt curvatures (Pruett *et al.* 1997). Recent studies have shown that cyclic fatigue is not the main mode of Ni-Ti rotary instrument fracture (Yared *et al.* 1999, Sattapan *et al.* 2000, Yared *et al.* 2000, Peters & Barbakow 2002). On the other hand, instruments can lock into the canal (Yared *et al.* 2001a) and be subjected to high levels of torsional stress, leading to deformation and fracture. Sattapan *et al.* (2000) showed that torque at fracture was significantly higher than torque during instrumentation. In their study, each set of instruments was used to prepare only one canal. Questions have been raised as to whether repeated use of Ni-Ti rotary instruments adversely affects their torsional properties and renders them more prone to torsional fracture.

Sattapan *et al.* (2000) compared the torque at fracture of new Quantec Series 2000 rotary Ni-Ti instruments (Tycom Corp.) to torque generated during root-canal preparation. Peters & Barbakow (2002) determined the torque and angle of rotation at fracture for only three sizes of ProFile Ni-Ti .04 instruments (Maillefer Dentsply). The determination of torque at fracture of new nickel titanium rotary instruments can be helpful for future comparative studies on the torsional properties.

This study was undertaken to compare torque (Nmm) and angle of rotation (degrees) at fracture of new and used Ni-Ti .06 K3 rotary instruments (SDS Kerr, Glendora, CA, USA). The relation between size of instrument and torque at fracture was also investigated.

## Materials and methods

### Evaluation of new instruments

Nickel–titanium .06 K3 rotary instruments (SDS Kerr) in sizes 15–40 were evaluated. Thirty new instruments of each size were tested for resistance to fracture by twisting according to ANSI/ADA Specification no. 28 (ANSI/ADA 1988). Two parameters were measured: torque (Nmm) at fracture and angle of rotation (degrees) at fracture in clockwise rotation.

*Apparatus and test*

A digital torque metre memocouple (A-Tech Instruments Limited, Scarborough, ON, Canada) measured torque with an accuracy of ±0.1 Nmm and angle of rotation with an accuracy of ±2° (Fig. 1). Prior to testing, each instrument's handle was removed with a suitable wire cutter at the point where the handle was attached to the instrument shaft. The shaft end was clamped in a chuck connected to a reversible geared motor revolving at a speed of 2 r.p.m. (Aerotech, Pittsburgh, PA, USA). A digital display amplifier controlled the operation of the motor. Three millimetres of the tip of the instrument were clamped tightly in another chuck with brass jaws connected to the digital torque meter memocouple and to a computer for measurement recording using the LabView software (National Instruments, Austin, TX, USA). A jig (Fig. 2) was constructed to ensure reproducible positioning of the tip of the instrument in the chuck.

*Statistical analysis*

Analysis of variance was used to compare the torque and angle of rotation at fracture amongst the different sizes of the new instruments. Pair-wise comparisons using Duncan's multiple-range test were completed to detect significant differences. The relation between size of instrument and torque at fracture was subjected to

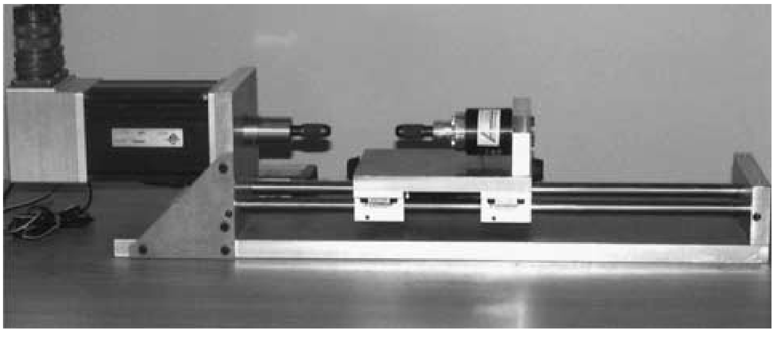

**Figure 1** Reversible gear motor (left) and torque-measuring device (right).

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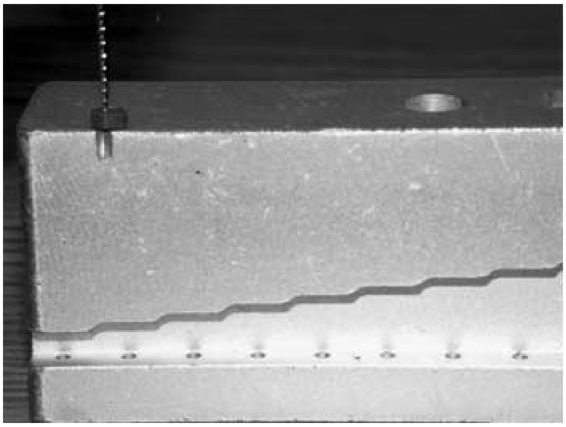

**Figure 2** Jig used to determine the clamping point in a reproducible manner (3 mm from the tip of the instrument).

regression analysis. Significance was determined at the 95% confidence level.

### Evaluation of used instruments

*Canal preparation and test*

Thirty sets of new Ni-Ti .06 K3 rotary instruments (SDS Kerr) sizes 15–40 were prepared. Each set of instruments was used with an 8 : 1 reduction handpiece powered by an electric torque control motor (Aseptico, Tulsa Dental, Dentsply, Tulsa, OK, USA) to prepare five endodontic resin blocks (Maillefer Dentsply) with curved canals in a crown-down manner. The canals were 17 mm long and presented a 45° curvature. Torque was set at level 3 on the motor. The instruments were used at 300 r.p.m. as recommended by the manufacturer (Kerr 2003). Canals were irrigated with 2.5% NaOCl and a syringe and 27-gauge needle. The canal preparations were completed by the same operator who was experienced in the technique. The instruments were used according to the following principles: the apical pressure exerted on each instrument was light (described as minimum pressure required to fracture the lead of a sharpened pencil), and each instrument was used with five to seven small in and out movements (3–5 mm) before switching to the next smaller instrument. Four to five recapitulations (waves) with K3 sizes 40–15 were required to complete canal preparation. The canal preparation was considered complete when a size 30 K3 reached the working length of 17 mm. The K3 sets were sterilized before each use by steam autoclave at 135 °C for 5 min; the entire sterilization cycle lasted 35 min. The instruments were inspected for deformation with ×2.5 magnification after each passage in the canal and before testing. The torque and angle of rotation at fracture of the instruments of the different sizes were determined as for the new instruments.

*Statistical analysis*

Analysis of variance was used to compare the torque and angle of rotation at fracture amongst the different sizes of the new and used instruments. Pair-wise comparisons using Duncan's multiple-range test were performed to detect significant differences between instruments of the same size. The relationship between torque at fracture and size of instrument was determined with regression analysis. Significance was determined at the 95% confidence level.

## Results

The mean torque at fracture and standard deviation for the new and used instruments are reported in Table 1. The means between the different sizes of the new instruments were significantly different ($P < 0.0001$). Between new and used instruments, for the same instrument size, the means were significantly different for sizes 15, 20, 30, 35 and 40 ($P < 0.0001$).

The mean angle of rotation at fracture, and standard deviation for the new and used instruments are reported in Table 2. The means between the different sizes of the new instruments were significantly different ($P < 0.0001$) except for sizes 15 and 20 ($P = 0.2561$). Between new and used instruments, for the same instrument size, the means were significantly different for sizes 20 ($P = 0.0185$), 30 ($P = 0.0055$), 40 ($P = 0.0093$), and sizes 25 and 35 ($P < 0.0001$).

A linear relationship was found between the size of the file and the torque at fracture for the new ($r^2 = 0.84$; $P < 0.0001$) and the used instruments ($r^2 = 0.82$; $P < 0.0001$). Figures 3 and 4 illustrate the relationship

**Table 1** Mean torque at fracture (gcm) and SD for new and used instruments

| | Size 15 | Size 20 | Size 25 | Size 30 | Size 35 | Size 40 |
|---|---|---|---|---|---|---|
| New | 7.68 (0.45) | 8.28 (0.46) | 9.20 (0.42) | 11.81 (0.38) | 13.65 (0.40) | 18.07 (0.89) |
| Used | 6.78 (0.49) | 6.78 (0.48) | 9.16 (0.33) | 11.12 (0.57) | 12.31 (0.22) | 15.80 (0.52) |

SDs are given in parenthesis.

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**Table 2** Mean angle of rotation at fracture (°) and SD for new and used instruments

| | Size 15 | Size 20 | Size 25 | Size 30 | Size 35 | Size 40 |
|---|---|---|---|---|---|---|
| New | 696.32 (40.74) | 719.26 (29.98) | 872.57 (52.48) | 1062.85 (182.16) | 1398.17 (39.36) | 1164.46 (61.70) |
| Used | 674.39 (80.26) | 671.53 (60.64) | 690.09 (31.45) | 1006.51 (109.80) | 1240.31 (74.16) | 1111.74 (26.57) |

SDs are given in parenthesis.

between the torque at fracture and the size of new and used instruments, respectively.

## Discussion

The angle of rotation and torque give valuable information about the torsional fracture, when an instrument binding in the root canal at its tip is rotated. The torsional properties of Ni-Ti rotary instruments can be investigated according to ANSI/ADA Specification no. 28 (ANSI/ADA 1988). Sattapan *et al.* (2000) considered ANSI/ADA Specification no. 28 inappropriate for Ni-Ti rotary instruments because the tests are performed under a static mode. However, recent studies showed that Ni-Ti rotary instrument fracture is mainly because of torsional stress (Sattapan *et al.* 2000, Peters & Barbakow 2002). When an instrument binding in a canal at its tip is rotated, the tip will be subjected to high levels of torsional stress. Instrument fracture will occur when the torsional stress at the point of fracture of the instrument becomes higher than the torque at fracture of the instrument. The test according to ANSI/ADA Specification no. 28 simulates an instrument binding at 3 mm from the tip in the root canal, and is therefore suitable to analyse the torsional properties of rotary instruments. The tests in the present study were conducted at 2 r.p.m. according to ANSI/ADA Specification no. 28, whereas in a clinical setting, the Ni-Ti rotary instruments are used at a minimum speed of 150 r.p.m. As a general rule, in a torsional loading model, the torque is independent of the twisting rate (rotational speed; Bailey 1985).

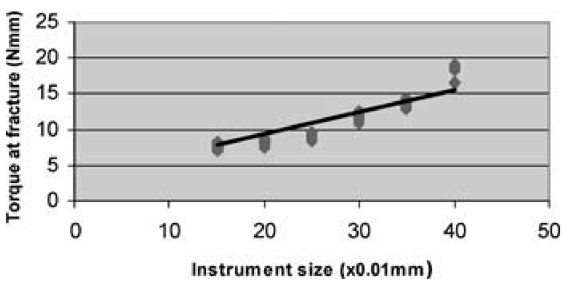


**Figure 3** Regression analysis (new instruments) indicating a linear relationship between instrument size and torque at fracture with $y = 0.3094x + 3.1657$; $r^2 = 0.8412$.

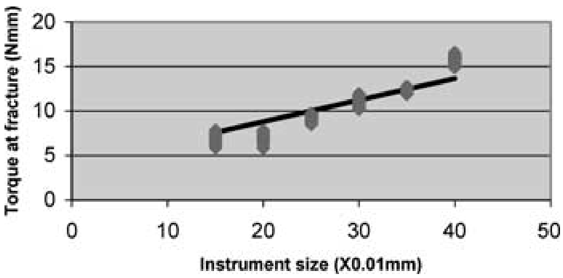


**Figure 4** Regression analysis (used instruments) indicating a linear relationship between instrument size and torque at fracture with $y = 0.242x + 3.9708$; $r^2 = 0.8205$.

Torque at fracture increased significantly with the diameter of the new instruments. Similar findings were reported in previous studies (Marsicovetere *et al.* 1996, Silvaggio & Hicks 1997, Sattapan *et al.* 2000, Peters & Barbakow 2002). Direct comparisons cannot be made because different instruments were investigated. Variations in the sample size and in the methodology could have also contributed to differences in the reported means torque at fracture. In the present study, 30 instruments of each size were evaluated as compared to only eight in the study of Peters & Barbakow (2002). Also, a jig (Fig. 2) was constructed to ensure precise positioning of the instrument tip in the chuck. In a preliminary study, the positioning of the instrument tip in the chuck without the use of the jig was inconsistent. The clamped length varied between 2 and 5 mm. An instrument clamped at 5 mm from the tip would show a higher torque at fracture compared to an instrument clamped at 3 mm.

The K3 .06 instruments were used in endodontic resin blocks to simulate repeated clinical use. Compared to extracted teeth, the resin blocks reduced variations in the instrumentation technique by limiting the variability of parameters such as canal length and width, canal anatomy, angle of curvature and the radius of curvature. However, resin blocks do not simulate the use of files in dentine; consequently, the results should be interpreted with caution.

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Different types of motors are used in conjunction with Ni-Ti instrumentation. Air motors, which are widely used, do not allow torque control, and variation in air pressure could affect the rotational speed and consequently the torque. For instance, a drop in air pressure would lead to a decrease in torque. The instrument would become less active, and the operator would tend to force the instrument into the canal because of which the instrument would be subjected to higher stress levels. Recently, a new generation of electric low-torque control motors has been introduced. These motors take into consideration the low torque at failure values of Ni-Ti rotary instruments.

In a pilot study, unsuccessful attempts were made to standardize the use of instruments (frequency and depth of insertions and the frequency of recapitulations). The attempt to standardize led to noticeable variation in the amount of pressure applied on the instruments by the operator. Consequently, it was impossible to standardize the actual wear on the instrument in the present study. One way to limit wear variations was to standardize the master apical file size in addition to standardizing, as much as possible, the frequency and depth of instrument penetration and the frequency of recapitulations.

In a previous study (Yared *et al.* 2000), it was noted that deformations went undetected if magnification was not used. The instruments were inspected for deformation with $\times 2.5$ magnification after each passage in the canal and before testing. When in doubt, the operator used brand new and deformed (unwound) instruments of the same size and taper as controls. None of the used instruments presented deformations or signs of damage. The use of a light microscope could have decreased the incidence of false negatives (undetected deformations).

The used instruments (sizes 15, 20, 30, 35 and 40) presented lower torque at failure with significant differences compared to the new ones. An SEM study of Ni-Ti endodontic rotary instruments showed a high incidence of surface defects where cracks are usually initiated (Kuhn *et al.* 2001). Cyclic fatigue, flexural or torsional, caused by the use of the instruments in a curved canal and by the repeated locking of the instruments in the canal (Yared *et al.* 2001a), could have facilitated the initiation and propagation of a crack (Kuhn *et al.* 2001), and therefore could have affected the torque of the instruments at fracture. Peters & Barbakow (2002) demonstrated that higher torque levels were generated in canals in resin blocks compared to canals in extracted teeth. The use of resin blocks probably subjected the instruments to higher levels of torsional stress, contributing to a higher incidence of crack initiation and propagation and lower torque-at-fracture values for the used instruments compared to the new ones. The canals in the endodontic resin blocks had a diameter of 0.20 mm at the working length. Consequently, instruments (sizes 15 and 20) should not have been subjected at the tip to high levels of stress during root-canal preparation, limiting crack formation. But, surprisingly, torque at fracture of used size 15 and 20 instruments changed significantly. The fact that the use of the instruments (frequency and depth of insertions and the frequency of recapitulations) was not standardized could explain the results obtained with the size 25 instruments. Most probably, the tips of these instruments were not excessively stressed during the root-canal preparation to a degree affecting the torque at failure.

The regression analysis, in accordance with the results of Camps & Pertot (1994) and Marsicovetere *et al.* (1996), showed a linear relationship between torque at fracture and instrument diameter ($r^2 = 0.84$). Direct comparisons could not be made because different instruments were investigated in the three studies.

A trend towards higher angle of rotation at fracture was observed with the larger new instruments. This finding was in accordance with data from a previous study (Silvaggio & Hicks 1997) and in contradiction with other documented results (Marsicovetere *et al.* 1996, Peters & Barbakow 2002). Differences amongst the studies could be attributed to variations in the type of instrument, sample size and methodology.

Lower angle of rotation at fracture values were obtained for the used instruments as compared to the new ones. Therefore, it seemed that torsional and flexural stress significantly affected the angle of rotation at fracture except for size 15 instruments.

## Conclusions

The results of the present study suggested that the torque at fracture of new instruments increased significantly with the diameter. The used instruments (sizes 15, 20, 30, 35 and 40) had lower torque at fracture compared to the new ones. The results also suggested that the angle of rotation at fracture was affected by the repeated use of .06 K3 instruments in resin blocks.

## References

ANSI/ADA (1988) *Specification no. 28 for Root Canal Files and Reamers, Type K.* New York: American National Standards Institute.


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Bailey J (1985) Fundamental aspects of torsional loading. In: xx. *Mechanical Testing*, Vol 8, 9th edn. Materials Park, Ohio: American. Society for Metals, pp. 140–4.

Barbakow F, Lutz F (1997) The Lightspeed preparation technique evaluated by Swiss clinicians after attending continuing education courses. *International Endodontic Journal* **30**, 46–50.

Camps J, Pertot WJ (1994) Torsional and stiffness properties of Canal Master U stainless steel and nitinol instruments. *Journal of Endodontics* **20**, 395–8.

Kerr (2003) http://docs.sybrondental.com/ads-cgi/viewer.pl/pubs/sybronendo/catalog/SybronEndo-CatalogV4.pdf?page=20.

Kuhn G, Tavernier B, Jordan L (2001) Influence of structure on nickel–titanium endodontic instruments failure. *Journal of Endodontics* **27**, 516–20.

Mandel E, Adib-Yazdi M, Benhamou L-M, Lachkar T, Mesgouez C, Sobel M (1999) Rotary Ni-Ti ProFile systems for preparing curved canals in resin blocks: influence of operator on instrument breakage. *International Endodontic Journal* **32**, 436–43.

Marsicovetere ES, Burgess JO, Clement DJ, del Rio CE (1996) Torsional testing of the Lightspeed nickel–titanium instrument system. *Journal of Endodontics* **22**, 681–4.

Peters OA, Barbakow F (2002) Dynamic torque and apical forces of ProFile .04 rotary instruments during preparation of curved canals. *International Endodontic Journal* **35**, 379–89.

Pruett JP, Clement DJ, Carnes DL (1997) Cyclic fatigue testing of nickel–titanium endodontic instruments. *Journal of Endodontics* **23**, 77–85.

Sattapan B, Nervo GJ, Palamara JEA, Messer HH (2000) Defects in rotary nickel–titanium files after clinical use. *Journal of Endodontics* **26**, 161–5.

Sattapan B, Palamara JEA, Messer HH (2000) Torque during canal instrumentation using rotary nickel–titanium files. *Journal of Endodontics* **26**, 156–60.

Silvaggio J, Hicks ML (1997) Effect of heat sterilization on the torsional properties of rotary nickel–titanium endodontic files. *Journal of Endodontics* **23**, 731–4.

Yared GM, Bou Dagher FE, Machtou P (1999) Cyclic fatigue of ProFile rotary instruments after simulated clinical use. *International Endodontic Journal* **32**, 115–9.

Yared GM, Bou Dagher FE, Machtou P (2000) Cyclic fatigue of ProFile rotary instruments after clinical use. *International Endodontic Journal* **33**, 204–7.

Yared GM, Bou Dagher FE, Machtou P (2001a) Influence of rotational speed, torque, and operator's proficiency on ProFile failures. *International Endodontic Journal* **34**, 47–53.

Yared GM, Bou Dagher FE, Machtou P (2001b) Failure of ProFile Instruments used with high and low torque motors. *International Endodontic Journal* **34**, 471–5.

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